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Aquaculture—A Star in Agriculture's Future

Four thousand years ago the Chinese began raising fish to eat. Today, that same practice—now called aquaculture—looms as one of the brightest stars in an agricultural galaxy too often troubled by high costs, low returns, and an indifferent public.

If this ancient practice is not yet fully conventional, it soon will be. Ten years ago, farm fish production in the United States was minimal. Today, 70,000 metric tons of fish are produced annually. According to the National Academy of Sciences that figure could rise to 250,000 metric tons by 1985. With appropriate private and government support, it could reach 1 million metric tons annually by the year 2000.

Farm-raised fish provide more return per pound of feed than any conventional farm animal—about one pound of fish for every pound and a half of feed. An acre of pond area can produce 3,000 to 9,000 pounds of fish annually. The number of pounds of fish per acre has grown as the knowledge of breeding habits, feed, space and oxygen requirements, temperature, water flow, and other factors has increased.

Adequate information exists for raising catfish, trout, and crawfish. This is quickly expanding for these and other food fish—Macrobrachium (a large fresh water shrimp), for example, and buffalo fish. The U.S. imports $2.6 billion of fish annually, an amount totaling 28 percent of its last year's net nonpetroleum related trade deficit.

Aquaculture is especially well suited to the small farmer. A farmer who raises fish exclusively can manage, with the proper equipment, as much as 100 acres of catfish ponds, and can produce an average of 3,000 pounds of fish per acre each year.

Aquaculture's future, at least for the immediate term, lies in fresh water fish where the technology is now available to raise them profitably. Americans eat a lot of fish, and little more of any of the traditional varieties, fresh or saltwater, can be caught anywhere without seriously depleting the natural supply. This means if Americans want more fish, they can import more, they can develop a taste for species not now used for food, or they can raise their own.

With current technology, fresh water aquaculture is profitable, but the individual farmers cannot, acting alone, develop the base of knowledge they would need to meet America's demand for fish over the next two decades. American farmers need an aquaculture plan—a plan that would provide them with research and specific data—so that they will be able to meet projected 1 million metric ton potential by the year 2000.

This would take a bold plan. The need for food for the American people and the world by the year 2000 is formidable.—Robert W. Deimel

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COVER: A laser beam penetrates a cloud of grain dust inside an experimental chamber where dust concentrations and particle size are measured. Such factors can become critical in detecting the conditions for a grain elevator explosion. SEA researchers in Manhattan, Kansas, are studying the physical and chemical properties of grain dust as part of a long-scale and multifaceted research project on grain dust explosions. (0778W923–4). Story begins on page 8.

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Bob S. Bergland, Secretary
U.S. Department of Agriculture

Anson R. Bertrand, Director of
Science and Education

Thornless blackberry "mother" plants kept in the greenhouse provide shoot tips for Broome to culture. The shoots will go through several disinfecting steps before they are placed in a sterile liquid medium (1278X1611–20A).

Tissue Culture Quickens Plant Propagation

TISSUE culture techniques being developed in horticultural research laboratories point to big changes ahead in propagation methods used by commercial producers of fruit and berry plants.

In the Fruit Laboratory at the Beltsville Agricultural Research Center in Maryland, for example, SEA plant physiologist Richard Zimmerman and colleagues are developing tissue culture techniques for apples and several kinds of berries.

Tissue culture is already in commercial use for some plants. Many of the house plants on the market today

Right: *Zimmerman and Broome examine a thornless blackberry culture to see if any adjustments need to be made in the nutrient medium (1278X 1639–30).*

Below: *A blackberry shoot tip "established" in liquid medium is transferred to an agar-based medium where it will produce a cluster of 20 to 40 new shoots. Extra leaves were removed so the shoot can be laid on its side, allowing it to absorb nutrients through a larger surface area (1278X1587–30).*

are propagated from tiny pieces of tissue that are induced to multiply rapidly in soil-free media containing nutrients and growth hormones. Several European countries have nurseries that use tissue culture to produce virus-free strawberry plants for commercial use.

When techniques being developed by SEA and other scientists are refined, they can "cut to a fraction" the time it now takes to propagate most fruit and berry plants, says Zimmerman. For example, the Beltsville scientists have produced 3,000 rooted strawberry plants from only one meristem (the growing tip of a bud) in the same amount of time it takes nurserymen to propagate 100 plants from 1 flourishing strawberry plant by rooting its runners.

Virus-free plants are more vigorous and productive, and tissue culture is an excellent way to obtain them from infected stocks. The virus-free technique has been used at Beltsville by John McGrew for more than 15 years. (See *Agricultural Research,* September 1966.)

Finding the best combination of nutrients and hormones to induce shoot production or root development is the crux of the research, says Zimmerman.

To get a culture started, the scientists implant the tip of an actively growing shoot, measuring about 1 centimeter long, in a jar containing nutrients and shoot-inducing hormones. The Beltsville team found that apple and blueberry shoot tips will "take" in an agar-based medium. However, thornless blackberry shoot tips do better when rotated in flasks containing a liquid medium for 2 to 3 weeks before they are transferred to the solid medium. Strawberry cultures are started from virus-free meristems less than 1 millimeter high implanted in an agar medium by McGrew.

After a shoot tip or meristem becomes established in its new environment, it begins sending out new shoots.

These new shoots are separated and transferred to fresh media to produce more shoots.

This multiplication process can be repeated every 3 to 4 weeks to produce thousands of shoots in a 4-month period.

Zimmerman got the best multiplication results with strawberries and thornless blackberries. A colleague, horticulturist Olivia Broome, recently counted 730 strawberry shoots in one 4-inch-diameter culture jar. Each of these shoots would root in fresh medium without the shoot-inducing hormone. Some strawberry cultivars root better when an auxin is added.

Thornless blackberries have an even greater multiplication potential because new shoots grow lateral shoots which can be divided and individually rooted in a peat and perlite mix, says Broome. She estimates that, starting with only one shoot tip, tissue culture "could yield two and one-half million cuttings for rooting in 28 weeks." . . . probably more than commercial propagators could handle. These cuttings develop a good root system in a greenhouse mist chamber without nutrients or hormones added to the medium.

On the other hand, apple shoots need nutrients and an auxin for good root development, and individual shoots are rooted in sterile culture conditions, not in the greenhouse. Zimmerman and colleagues have gotten up to 60 percent rooting success using a liquid medium added to a vermiculite-perlite base, but are aiming for at least 90 percent. The multiplication rate and rooting percentage for apples is still too low for commercial use, says Zimmerman. He hopes to have a commercially useful technique within 2 years.

Research on blueberries is still in the early stages.

Dr. Richard Zimmerman is located in Room 118, Building 004, Beltsville Agricultural Research Center-West, Beltsville, MD 20705.—J.McB.

Above: *Broome removed this mass of apple shoots still in its agar-based medium from a 4-inch culture jar to demonstrate shoot production. About 75 shoots have grown from a few small clusters implanted 4 weeks earlier (1278X1607–10A).*

Below: *Johnny Appleseed may have started this orchard, but a tissue culture technique for the propagation of apple trees may be the basis for apple orchards of the future (051–6–28).*

Dietary Fiber Reduces Egg Cholesterol

High-fiber feed for these chickens could mean less cholesterol in the eggs they lay (0274K220–30A).

FEEDING dietary fiber to laying hens can reduce the cholesterol content of egg yolks by as much as 13 percent.

SEA animal scientist James L. McNaughton noted no significant differences in either egg production or egg weights due to the high-fiber diet.

Since most of the cholesterol in eggs is located in the yolks, a 13-percent reduction represents a significant overall reduction of egg cholesterol.

McNaughton fed the laying hens dietary fiber in two experiments. He used fiber from diverse sources including corn, soybean, alfalfa, sunflower, rice, and wood shavings.

The greatest reduction in egg yolk cholesterol occurred when the scientist fed the hens fiber from sunflower meal. He recorded a 13.3-percent reduction of yolk cholesterol when the laying hens were fed a diet that contained 8.8 percent sunflower meal fiber.

The other fiber-containing diets were less successful. Interestingly, however, egg yolk cholesterol was reduced by about 10 percent when about 10 percent fiber from wood shavings was added to the diet.

The scientist is not sure why the reduction in yolk cholesterol occurs from the high-fiber diet. "Apparently," says McNaughton, "coarse dietary fibrous materials cause a scraping in the small intestine and the cells of the villi are scraped off. Since a high concentration of cholesterol is found in these cells, total body cholesterol is decreased causing a subsequent reduction of yolk cholesterol."

Dr. McNaughton is with the South Central Poultry Research Laboratory, Mississippi State, MS 39762.—B.D.C.

Breeding Progress in Forage Feeding

A RECENTLY completed SEA study has confirmed that present methods of selecting superior dairy cattle are moving in the right direction and should be continued despite changes in production practices by the industry.

Feeding large volumes of grain to dairy cattle has been responsible for great increases in milk production over the past two decades, but several years ago a grain shortage forced farmers to rely more on forage feeding. As the growing world population places greater demands for grain as human food, it seems that forage feeding is here to stay.

Selections of present-day dairy cattle breeding stock have been made on the basis of a high grain diet. The dairy industry is concerned that these selections won't perform as well when switched to a high forage-low grain diet. Recent findings show that these concerns are unfounded.

Through a long-term study begun in May 1961, SEA researchers established that a high genetic relationship between efficiency and milk production exists. The latest phase of the project has now shown that the most feed efficient animals are also the highest milk producers regardless of their diet (grain or forage).

In this latest phase, daughters of United States, Canadian, and New Zealand bulls (where animals are fed a strictly forage diet) were divided into two, equal-size groups. One group was fed a high forage-low grain diet, the other a high grain-low forage diet.

The efficiency with which the animals could convert their feed to milk

was studied, and it confirmed that a genetic influence exists, which means selective breeding can be used. Also, the inheritance of feed efficiency proved to be about the same as the inheritance of milk production abilities. Had this not been the case, breeders would have to start measuring feed intake as well as milk production in order to make their selections.

Though the cows on a high forage diet produced only 70 percent of the milk that cows on a high grain diet produced (this is attributed to the nutritional differences between grain and forage), the daughters of bulls that did best on grain also did best on forage, showing that present selective breeding techniques are correct.

The study was originally conceived by geneticist R. Dean Plowman, current director of SEA's Utah-Montana-Idaho Area. It was completed by SEA geneticist Robert C. Lamb and SEA nutritionist Melvin J. Anderson.

All are now located at the Agricultural Sciences Building, Utah State University, Logan, UT 84321.—L.C.Y.

Soybeans Susceptible to Tan Spot

BACTERIAL tan spot, a new soybean disease, has been found in Iowa by SEA plant pathologist John M. Dunleavy.

Dunleavy says he confirmed the disease in soybean plant samples from eight counties in Iowa after he first identified symptoms of the disease in his soybean research plots at Ames in 1975. He informed Extension Service workers and research colleagues of the characteristics of the disease; they began to look for it and brought him diseased samples from fields and research plots.

Dunleavy began running tests of commonly grown soybean varieties to evaluate their susceptibility to bacterial tan spot in 1977, and to find out how serious the problem might be. He found a broad range of resistance among the 20 varieties field tested. Three of the older varieties, Chippewa 64, Clark 63, and Rampage, were the most susceptible.

Dunleavy also noted that bacterial tan spot is more destructive to the leaves of the susceptible varieties than bacterial pustule and bacterial blight.

When he inoculated seedings with bacterial tan spot, the disease moved through susceptible varieties to reduce yields by as much as 8 percent.

"Tan spot is particularly damaging if it occurs early in the season as it continues to spread throughout the growing season," Dunleavy says. The most resistant of the varieties tested were Amsoy 71, Beeson, and Harcor.

The other 14, showing some resistance to bacterial tan spot, were: Calland, Coles, Corsoy, Cutler 71, Hark, Harosoy 63, Hawkeye 63, Hodgson, Marion, Steele, Wayne, Wells, and Woodworth.

Dunleavy says that bacterial tan spot is caused by *Erwinia herbicola*, a yellow bacterium, which begins with a small lesion on a leaf that may enlarge to encompass the entire leaf. The first symptom is chlorosis (yellowing), which frequently starts at the leaf margin and progresses to the midrib—eventually killing the infected part of the leaf which then dries out and turns brown. These large areas may fall out of the leaf during windy weather.

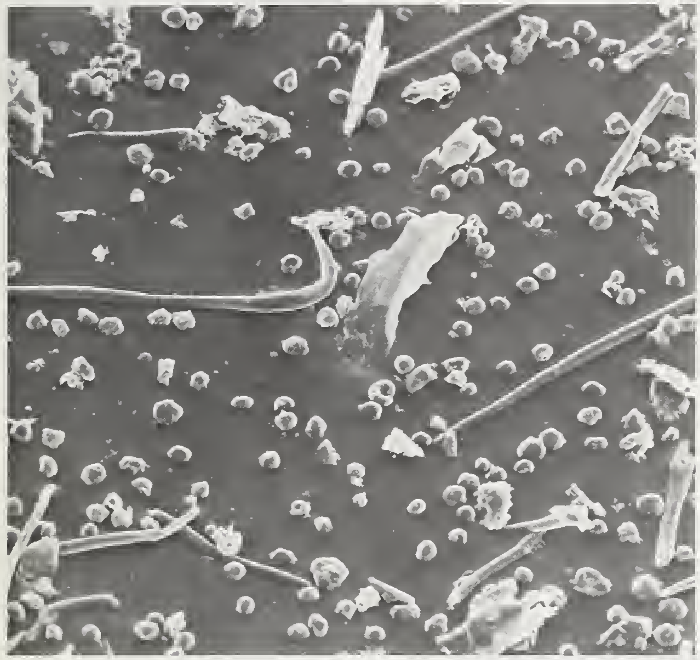
"The disease spreads rapidly in the very susceptible varieties," Dunleavy says. "Although yield losses can occur in these varieties, the main thing we must do is determine which breeding lines carry resistance to bacterial tan spot and try to breed that resistance into new seed releases in order to avoid serious outbreaks."

Dr. Dunleavy is located at the Department of Botany and Plant Pathology, Iowa State University, Ames, IA 50011.—R.G.P.

A PROGRESS REPORT ______ Grain Dust Explosic

Above: At the firing console, cooperating Kansas State University physicist Ronald Lee sparks a measured amount of grain dust in "Hartmann bomb" tests to determine the minimum dust concentrations necessary for an explosion (1178X1547–22).

Right: Burning grain sends black smoke into a December 1977 afternoon as a chain-reaction of explosions destroys this export elevator at Westwego, La. Thirty-six persons were killed, and eight more seriously injured (PN–4182).



Scanning electron micrograph shows wheat dust particles obtained from a cyclone dust collecting system in a commercial grain elevator. Such micrographs aid researchers in studying the proximity and physical characteristics of dust at selected elevator locations (PN–4181).

Research

FOR an explosion to occur in a grain elevator, an automobile engine, or other confined space, there must be combustible fuel, oxygen, and a spark.

If the fuel is dust, it must also be finely divided, dispersed in the atmosphere, and in a great enough concentration to cause an explosion. And the spark must produce enough heat, and fast enough, to initiate combustion of the dust involved.

SEA chemist Byron S. Miller says explosibility of grain dust probably is affected by particle size, chemical and physical composition, moisture content, relative humidity, temperature (of grain, dust, and air), and concentration of flame-supporting and contaminant gases.

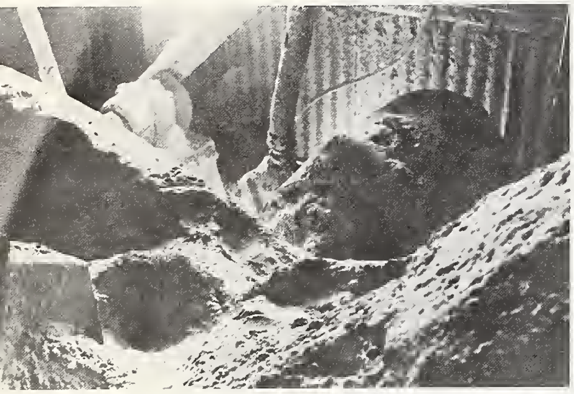
Engineers and scientists at the U.S. Grain Marketing Research Laboratory, Manhattan, Kans., are making detailed studies with dust from corn, wheat, grain sorghum, and soybeans with the ultimate objective of developing practices or devices that will minimize the possibility of grain dust explosions.

An average of 8 dust explosions occurred in U.S. grain elevators each year between 1958 and 1975, with a total of 36 persons killed and 211 injured. Explosions in Louisiana and Texas export elevators in December 1977 claimed 53 lives.

Grain elevators have ranked first in incidence of agricultural dust explosions since 1860, and the industry has long enforced preventive housekeeping and safety measures. More recently, elevators have installed dust collection systems in compliance with air pollution control regulations.

All grain contains some dust Miller says, in amounts ranging from less than 0.02 percent to more than 0.1 percent. Dusts from different grains vary in composition as do samples of dust from the same grain. Some grains, particularly corn, create additional dust each time they are handled. The total U.S. grain supply, much of it handled many times, has averaged 250 to 300 million metric tons most years since 1962.

A dust explosion in an elevator might be ignited by heat, flame, or a spark from many sources—a slipping belt, a hot bearing, a faulty electrical system, welding, a nail in a shoe, unauthorized smoking.



Fire trap: looking like the corroded remains of a sunken ship, this scene of grain dust piled high and around grain elevator machinery is typical of the kind of hazard that can arise in an improperly managed grain storage operation (PN–4183).

Studies at the federal research laboratory and under cooperative agreements with Kansas State University, Manhattan, are underway in these areas: physical and chemical characteristics of grain dust explosibility, monitoring explosibility hazards, reduction of dust formation, and utilization of dust.

What are the physical and chemical properties of grain dust?

In a study of dust from collection systems of commercial elevators, SEA agricultural engineer Charles R. Martin found that dust particles vary not only in size, but also in average specific density, which means that some dust particles of about the same size are heavier than others.

He found that dusts contain varying amounts of combustible material—corn dust the most, and proportionately less in wheat, sorghum, and soybean dust. The noncombustible material is concentrated in the fine dust.

Coarse dust and the combustible part of fine dust from corn, wheat, and sorghum had nutritional values—protein, fat, and starch—comparable to those of the grain from which it was generated, but generally more fiber.

SEA chemical engineer Fang S. Lai and Martin are now determining the characteristics of dust collected at different locations in commercial elevators. Amino acid analysis will be included in the study to further define the nutritional value of grain dust.

What initiates, triggers, and propagates dust explosions?

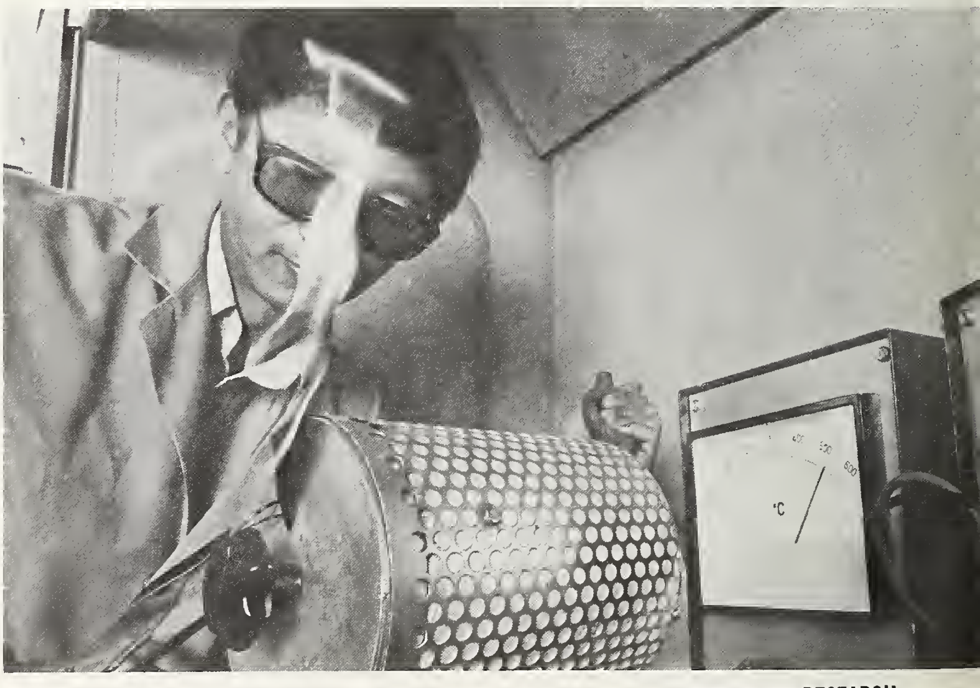
Lai is producing bench-scale dust explosions with the Hartmann bomb, a device designed by the U.S. Department of the Interior's Bureau of Mines for study of coal dust explosions and built from the Bureau's plans by SEA engineering technician Robert Rousser. Lai is reconforming and expanding on data developed by the Bureau of Mines in extensive studies several years ago to better define four dust explosion criteria for grain dusts of different kinds and particle sizes:

—*Minimum ignition energy* might be described inexactly as how big a spark is needed to ignite each dust. Lai is also determining the effect, if any, of static electricity.

—*Maximum pressure rise* relates to extent of damage—the higher the pressure rise the greater the damage.

—*Maximum rate of pressure rise* depends upon both kind and concentration of dust, may determine the feasibility of warning or explosion-suppression devices. Unless the rate of pressure rise is gradual, the explosion would occur before such a device could be set off.

—*Minimum explosion concentration* is how much dust must be dispersed in the air before an explosion can occur. A



490 . . . 495 . . . 500 degrees centigrade! In tests to determine the combustion properties of grain dust, Lai squeezes an air bulb leading into a miniature laboratory furnace as the dust inside the furnace reaches the minimum temperature for catching fire (1178X1546–10).

cloud of dust might explode, Lai explains, while a pile of dust might burn but will not explode.

Kansas State University physicist Ronald S. Lee working with Lai is also using the Hartmann bomb to develop a model of grain dust explosion—a way of describing the conditions under which such explosions occur.

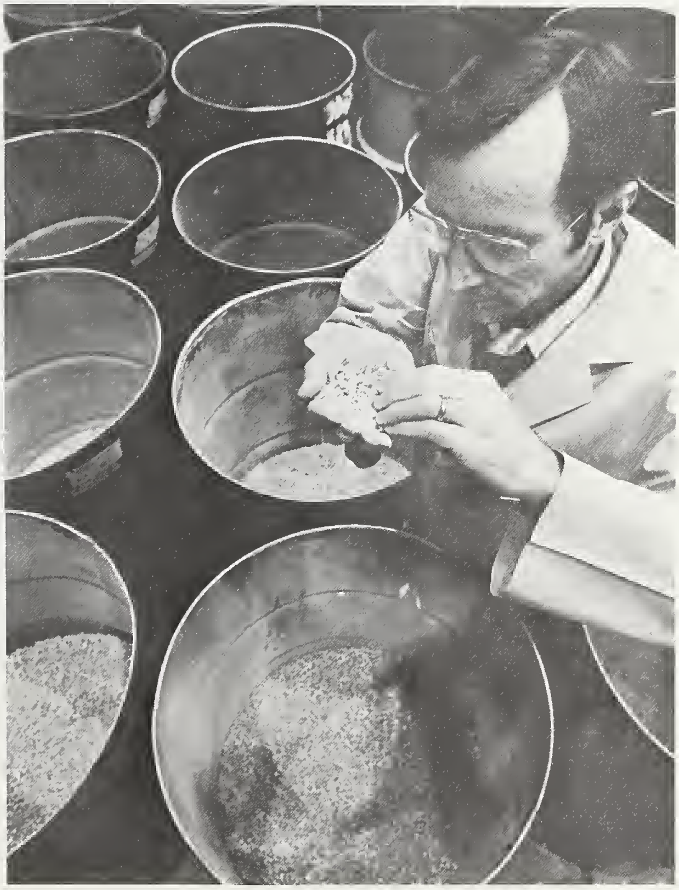
Also at Kansas State, mechanical engineer Thomas W. Lester is identifying the detailed chemical and physical processes involved in ignition and subsequent formation of detonation waves in dust clouds. He uses a chemical shock tube, a device in which pressure is built up and then suddenly released through a tube 60 feet long. The shock wave strikes and explodes a 20-milligram sample of grain dust.

Gases in grain bin air, including those from fumigants, might contribute to grain dust explosions. So Kansas State chemical engineer John C. Mathews is determining how carbon monoxide, methane, carbon disulfide, and carbon tetrachloride atoms adhere to dust particles under a range of temperatures. He also is measuring surface areas of corn, wheat, sorghum, and soybean dust as well as air spaces between and within dust particles.

How can potentially explosive dust conditions be monitored in elevators?

A device for simultaneously measuring dust concentrations and particle sizes—sampling takes less than one-thousandth of a second—is being tested by Jon J. Held, Kansas State graduate student working at the SEA laboratory. The test is based on the principle that dust scatters light, and each particle size has a unique dispersion pattern. A laser beam, only 2 milliwatts power, is directed through a dust sample to photodiodes that pick up light-scatter patterns with data recorded by computer.

Left: *Corn passed through a grain accelerator at speeds up to 100 feet per second simulates the dust and fragments that result when grain falls into a barge, ship, or railroad car (0778W918-4A).*
Below: *Agricultural engineer Charles Martin inspects grain that has been treated with mineral oil to inhibit dust. Each of the drums in this study contains different proportions of oil and grain. Research indicates that an economical 200th of 1 percent oil mixture is adequate (1178X1561-7).*



How can dust formation be reduced or prevented?

Miller, Lai, and Martin have run pilot-scale tests adding water to grain before it is moved in the elevator. Drawbacks would be the necessity of adding water each time the grain is moved, and the possibility of building up grain moisture levels that would support mold growth. The engineers are studying the one-time addition of soybean oil or mineral oil. Perhaps the oil could be the carrier for a grain protectant applied at bin-filling time.

Any improvement in grain-handling methods that decreases kernel damage would also reduce dust formation. Miller, in basic studies of grain breakage, has designed an accelerator that

simulates in a 1-meter drop the action of grain falling 100 feet. With high-speed photography, he can "see" what happens as kernels strike a bed of grain and bounce, setting other kernels in motion both vertically and horizontally.

How can dust removed from grain be used?

An elevator operator has less grain to sell than he bought, because of dust created in handling, and takes a financial loss if there is not an alternate use for the dust. A logical approach to good dust management, Martin points out, would be to treat dust as a byproduct to be used as feed, fuel, or fertilizer. If economically feasible, the dust might be pelleted as a livestock feed ingredient. Research by Martin on characteristics of grain dust has established its nutritional value. Work on extrusion of dust into usable form for feed is underway at Colorado State University.

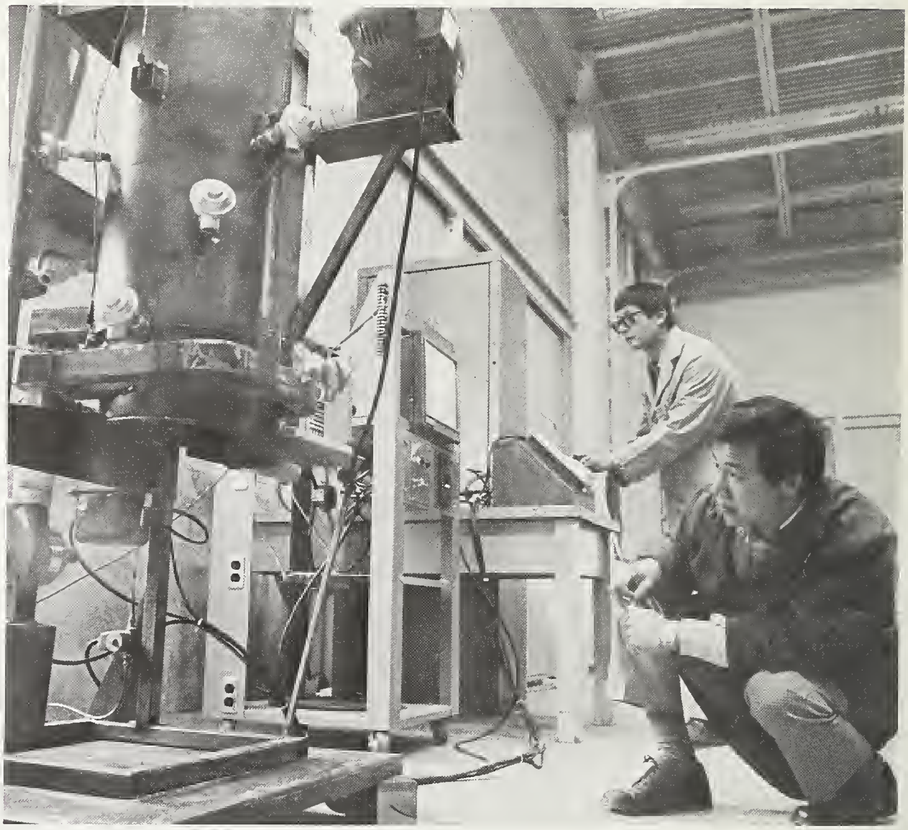
What engineering knowledge from study of other kinds of dust explosions might be applied to the grain dust problem?

A detailed and critical analysis of literature by David F. Aldis, Kansas State chemical engineer working with Lai at the laboratory, may furnish clues and new perspectives from past studies.

But SEA is studying all aspects of the problem—dust characteristics, explosibility, monitoring, prevention, and utilization—to find ways of minimizing or preventing grain dust explosions.

Dr. Bryon S. Miller, Charles R. Martin, and Dr. Fang S. Lai are located at the U.S. Grain Marketing Research Laboratory, 1515 College Ave., Manhattan, KS 66502—W.W.M.

Grain dust can be collected and compressed into pellets for mixing with animal feed. Rod-shaped pieces are made by an extrusion process (1178X1560-3).



Agricultural engineer Cheng Chang (foreground) and Lai burn grain dust in an experimental furnace that generates enough heat (up to 100,000 Btu's per hour) for an average-size home during a Kansas winter. The grain dust furnace could also warm the air for grain-drying operations (1178X1540-16A).

Chemical Weed Control During Fallow

Smika examines 14-month-old undisturbed wheat stubble.

USING herbicides to control weeds during fallow is one more management technique that farmers and ranchers on the Central Great Plains can use to increase the odds for a successful higher yielding wheat crop. Fallow is the period when fields are not planted to crops. This allows soil moisture to accumulate for the next crop's use if weeds are controlled.

Grain yields on lands where herbicides alone were used to control weeds during fallow averaged 44 bushels per acre. Conventional fallow, which uses sub-surface tillage to control weeds, produced grain yields that averaged only 34 bushels per acre.

SEA research shows that when soil is not tilled, only the top 1 to 1½ inches of soil dries—no matter how long between rainfalls.

All too often, limited precipitation and uneconomical use of available moisture means crop failure for vast acreage of wheat lands from Canada to Texas. When farmers apply herbicides during fallow, weeds do not grow and the limited amount of moisture that is in the soil remains for the next crop.

When the best mechanical tillage methods available today are used, moisture storage during fallow rarely exceeds 35 percent. However, when contact and pre-emergence herbicides and no tillage are used, water storage has been as high as 60 percent and averages above 52 percent during fallow.

Why? Although tillage controls weeds, each pass of the tillage tool over the field results in soil drying amounting to as much as one-third inch loss in 24 hours. Herbicides kill weeds without disturbing the soil.

Tillage to control weeds is not usually performed until weeds are 2 to 3 inches high. By this time, weeds have removed much valuable soil moisture. This moisture loss can make the difference between a crop and no crop. Pre-emergence herbicides kill weeds before they emerge and before they have used moisture.

"We learned that replacing tillage with chemicals during fallow results in more dependable crop production," says soil scientist Darryl E. Smika.

A major additional benefit of herbicide fallow will be cleaner air because leaving all crop residue on the soil surface will protect against wind erosion. These residues are often destroyed during tillage. Also, using conventional tillage increases soil susceptibility to wind erosion by 20 to 25 percent compared to virtually zero for chemical control during fallow.

Cost for chemical control is about $18 to $24 per acre compared to an estimated $17 to $23 for conventional tillage fallow. "Chemical weed control reduces fuel consumption by 50 to 70 percent and increases wheat yield by 10 bushels per acre," adds Smika.

Dr. Smika is located at SEA's Central Great Plains Research Station, P.O. Box K, Akron, CO 80720.—D.H.S.

Insects Enticed to Ingest Virus

Lacing an insect virus with sugar and other palatable nutrients is a ploy scientists are using to get destructive insects of cotton and other crops to ingest the "biological insecticide."

Insect viruses are lethal to their hosts. One, a nuclear polyhedrous virus (NPV) from the alfalfa looper, is fatal to a wide range of cotton insects, including pink bollworm, cabbage looper, tobacco budworm, beet armyworm, alfalfa looper, cotton leafperforator, and salt marsh caterpillar. It is not yet registered for use on cotton. A commercial NPV with a limited range—tobacco budworm, bollworm—is registered, however.

After susceptible insect larvae have ingested the virus, larvae's body cells produce virus instead of carrying out normal pursuits. Within days the insect is practically liquified. Since the disease is a "natural enemy" and attacks only certain insect pests—environmental impact is nil.

When the virus was first isolated and later produced in quantities sufficient to be used experimentally to dust on crops or added to water and sprayed, the idea was greeted enthusiastically by scientists and farmers alike.

For some reason, between theory and actual practice, results were less than expected. This could have been because the insects were not cooperating by ingesting the virus in quantities large enough for the needed impact.

That's where the idea of a "spoonful of sugar" came in to "bait" the virus with something the insects would ingest.

While several adjuvants or baits have been developed since that time, to date none are in use on cotton in large amounts. SEA entomologist Marion R. Bell, has developed an adjuvant that shows promise for commercial use with the viruses on cotton for control of tobacco budworms.

Bell's adjuvant plus virus (NPV from the alfalfa looper) was field applied last October to late-planted cotton, along with another plot sprayed with virus but without the adjuvant. Another plot was left untreated.

Results showed that the adjuvant significantly increased the effectiveness of the virus against the tobacco budworm. Average mortality due to virus infection of larvae collected from plots treated with virus plus adjuvant was 71 percent compared to 47 percent of those larvae collected in plots treated only with the virus. The mortality percentage of larvae from the untreated cotton was only 1.8.

In greenhouse tests, the adjuvant compound of cottonseed flour, crude cottonseed oil, and sugar produced 93 percent mortality due to viral infection after 10 days. In the same test, larvae exposed to virus and water alone produced 33 percent mortality.

At 14 days after beginning virus treatments in the field tests, the average number of live larvae per plant was 1.4, 2.4, and 6.5 for the adjuvant/virus, virus alone, and untreated plots respectively. The same date also showed that there were almost twice as many undamaged bolls in the adjuvant/virus plots as in the untreated plots, indicating a decrease in the loss of cotton to this pest. The number of larvae in the fruiting forms of the plants was reduced about 85 percent in the virus plus adjuvant treatment as compared with the untreated plot.

Results also showed that when the adjuvant was used there was a faster reduction of the insect population, thus, less damage to the plant after larval infection.

Applying the virus to cotton in the adjuvant spray also helped protect the virus from deactivation by the environment and increased its persistence. At 3 days after application, adjuvant treatment samples indicated that 54 percent of the activity remained. The virus sprayed alone had only 20 percent activity. That fact should aid in reducing frequency of application required for control when the adjuvant is used.

Bell is studying the addition of other properties to the adjuvant that may protect the virus against ultraviolet light from sunlight or evaporation of the formulae.

Cost of this adjuvant is about $0.35 per pound. In each application of the field test, 5 pounds of adjuvant were applied per acre with approximately $2 worth of virus.

Losses to cotton from tobacco budworms and other insects are estimated in the hundreds of millions of dollars annually, with many millions more spent on insecticides. Biological control methods such as the use of viruses could reduce both losses due from insect damage and insecticide use. If nothing else, the use of viruses spiked with an adjuvant along with other control methods in an integrated program of control could cut the frequency of insecticide use.

Dr. Bell is stationed at SEA's Western Cotton Research Laboratory, 4135 West Broadway Road, Phoenix, AZ 85040.—J.P.D.

The More Bitter the Better

BEER drinkers rejoice! The future of new, more bitter than ever, hop varieties looks bright. A SEA chemist has discovered a quick way to determine, for the first time, a male hop plant's contribution to the bitterness of a new hop variety.

Beer gets its bitterness from the brewing of hop plants.

Both hop growers and beer producers want new hop varieties that display superior bitterness. Currently, foreign hop varieties tend to surpass our domestic varieties in bitterness and, consequently, our varieties suffer in international competition.

The bitterness in hops comes from a substance called alpha acid which is produced by lupulin glands in a hop flower. Analyzing a hop's lupulin glands for alpha acid content easily determines the plant's bitterness qualities. A female hop flower contains 15,000 to 20,000 lupulin glands which are readily extracted for analysis from the base of the female's petals.

Male flowers, however, possess only 10 to 100 lupulin glands, hidden away deep in the male anthers or pollen sacks and, until now, there's been no way to isolate these glands for analysis. Hop breeders could only estimate the male's effect on its progeny's bitterness by observing the progeny—a long, costly, and not too accurate procedure.

SEA chemist Sam T. Likens, Corvallis, Oreg., working with SEA plant physiologist Charles E. Zimmerman, Prosser, Wash., and Gail Nickerson, a chemist with Oregon State University, has developed a method by which the male lupulin glands can be quickly isolated and analyzed for alpha acid content just like the female lupulin glands. Male hops with a high alpha acid content can then be identified and used to pollinate high alpha acid females to obtain a progeny with superior bitterness.

Likens' method is surprisingly simple. The flowers from a male hop plant are placed in an electric blender, water is added and the blender is activated for a few moments. The plant's lupulin glands float to the surface of the resulting slurry as tiny, yellow grains. The slurry is passed through a strainer and the lupulin glands are collected and analyzed.

Using this new technique, Likens can completely evaluate 20 male hop plants for their bitterness qualities in a single day. Before, it would have taken 2 years for hop breeders to make estimations on as many plants by progeny observation. Likens' technique can also be used to measure a male hop plant's storage stability.

The new technique has shown that both male and female lupulin glands can range from 0 to 60 percent alpha acid content. If a female plant with lupulin glands containing the maximum 60 percent alpha acid is pollinated with a male whose lupulin glands contain no alpha acid, the offspring's alpha acid content will be diminished and its bitterness quality will suffer. Likens' technique will enable such mismatches to be avoided in the future.

Drawing a distinction between bitterness and flavor, Likens feels that a hop's flavor also comes from its lupulin glands and he plans to use the technique to search for whatever is responsible for that flavor. Once that knowledge is attained, improving a hop's flavor—like improving its bitterness—will no longer be a matter of guessing for breeders.

Likens is located at Room 437, Weniger Hall, Oregon State University, Corvallis, OR 97331.—L.C.Y.

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Airpillows Cushion Tomato Loss

AIR-INFLATED PILLOWS or cushions can lessen the impact when tomatoes are dropped during handling from field to cannery. Use of these pillows could reduce substantially the $34 to $40 million annual loss in California tomato production. Most of this loss is caused when tomatoes are dropped from mechanical harvesters into collection bins or larger bulk containers for transport to canneries.

Simulated harvest experiments by SEA chemical engineer John M. Krochta show that the cushions can reduce severe damage (cracks or crushing) by 34 to 52 percent. Moderate damage (splits in skin) is reduced 12 to 25 percent and the number of undamaged tomatoes is increased by 8 to 17 percent.

The cushions were developed to lie on the bottoms of harvest containers. When inflated, they reduce the distance tomatoes must fall, thus reducing damage. As more tomatoes are added, the cushions automatically deflate to return the entire container volume.

"However, several challenges remain. We still need to fabricate air-cushions and pressure-relief valve systems for larger-scale industrial use," says Krochta. "These designs must allow for present grading-station sampling and easy unloading and avoid any sanitation problems. If the cushions prove successful in the tomato industry, they probably could reduce damage to other fruits and vegetables."

Krochta is located at the Western Regional Research Center, 800 Buchanan Street, Berkeley, CA 94710.—D.H.S.

Stored Seed Survive

GRASS AND CLOVER SEEDS can be stored at subfreezing temperatures for long periods of time and still produce as much forage when planted as fresh seed, a SEA researcher has proven.

For years, researchers have been storing seeds to assure future generations of forage resources without any real knowledge as to whether or not the seed would perform following prolonged periods of storage.

Clarence M. Rincker, SEA agronomist at Prosser, Wash., has demonstrated that forage seed can be frozen, thawed, refrozen, and rethawed over long periods of time without a loss of productive ability providing the stored seed was of high quality to begin with.

Working only with forage seeds, Rincker began his studies 20 years ago. Since that time he has stored over 4,000 seedlots at subfreezing temperatures and tested 300 of these lots at various intervals.

Others have reported on whether seeds stored in subfreezing temperatures will germinate, but Rincker is the first to test stored seeds for performance after germination. The final evaluation of his lots will not be made until 1980, but to date, all lots have lost little if any viability because of subfreezing storage.

Rincker is located at the Irrigated Agriculture Research and Extension Center, P.O. Box 30, Prosser, WA 99350.—L.C.Y.

When reporting research involving pesticides, this magazine does not imply that pesticide uses discussed have been registered. Registration is necessary before recommendation. Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if not handled or applied properly. Use all pesticides selectively and carefully.

PROTECT
Use Pesticides Safely
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